POWDER COMPACTION PRESS AND METHOD FOR MANUFACTURING OF CAPACITOR ANODES

TECHNICAL FIELD

[0001] This invention relates to a powder compaction press and a method for making capacitor anodes.

BACKGROUND OF THE INVENTION

[0002] Compaction of tantalum or valve powder to make capacitor elements is known in the art as evidenced by the disclosure of U.S. Patent 5,949,639 issued September 7, 1999 to T. Malda et al. for a Capacitor Element for Solid Electrolytic Capacitor, Device and Process for Making the Same and by the disclosure of U.S. Patent 6,191,936 issued February 20, 2001 to D.A. Webber et al. for a Capacitor Having Textured Pellet and Method for Making Same.

[0003] When making capacitor anodes by compaction of valve powder it is desired to have uniform compaction. However when the capacitor element has an irregular exterior surface the compaction device typically does not produce a uniformly compacted capacitor element. It has also been found that the capacitor element may be damaged by the withdrawal of the punches used in forming such an element.

SUMMARY OF THE INVENTION

[0004] It is a primary object of the invention to form a capacitor element having an irregular exterior surface by compacting valve powder in such a way that the degree of compaction is uniform throughout the element. It is also an object of the invention to provide a powder compaction press which uniformly compacts a capacitor element having an irregular exterior and which does not damage the capacitor element when the forming punches are withdrawn from the capacitor element.

[0005] The capacitor element is formed in a horizontal press or in a vertical press using opposed rib punches and opposed channel punches arranged in interleaved fashion. The opposed rib and channel punches are so positioned in their non compacting position, in which powder in the compression chamber is not under compression, that in traveling to their compression positions the powder will be compressed to the same degree throughout the capacitor element. After the capacitor element is formed, the opposed channel punches are withdrawn first to avoid friction destruction of the element.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Two embodiments of the invention are illustrated in the drawings in which

Figure 1 is a top view of a first embodiment in the form of a horizontal press with parts broken away for illustration purposes;

Figure 2 is a view taken on line 2-2 in Figure 1 with parts broken away for illustration purposes;

Figure 3 is a view taken on line 3-3 in Figure 1;

Figure 4 is a partial top view of the press of Figure 1 showing rib and channel punches in their non-compacting position;

Figure 5 is a top view similar to Figure 4 showing powder deposited in the compression chamber;

Figure 6 is a top view of the compression chamber showing the rib and channel punches in their compacting positions and the capacitor element in its compacted condition;

Figure 7 is a top view of the compression chamber showing withdrawal of the channel punches from the capacitor element;

Figure 8 is a top view of the compression chamber showing the rib and channel punches withdrawn from the capacitor element;

Figure 9 is a top view showing withdrawal of a pair side walls of the compression chamber;

Figure 10 is a section of a prior art press showing powder in a compression chamber prior to compaction;

Figure 11 is a section showing the punches of the prior art press of Figure 10 in their compaction position;

Figure 12 is a section showing the punches of the prior art press withdrawn from the compacted capacitor element;

Figure 13 is a perspective view of a capacitor element with a single lead wire;

Figure 14 is a perspective view of a capacitor element with three lead wires;

Figure 15 is a perspective view showing a modified capacitor element;

Figure 16 is a view taken on line 16 – 16 in Figure 15;

Figure 17 is a side view of a second embodiment in the form of a vertical press with parts broken away for illustration purposes;

Figure 18 is a view taken on the line 18 – 18 in Figure 17;

Figure 19 is a partial side view with parts broken away to show a compaction chamber filled with powder;

Figure 20 is a partial side view showing upper rib and channel punches lowered to the top of the filled compaction chamber;

Figure 21 is a partial side view showing the rib and channel punches adjusted to a desired pre-compaction position, and

Figure 22 is a partial side view showing the rib and channel punches in their compacting positions and the capacitor element in its compacted condition.

DETAILED DESCRIPTION OF THE INVENTION

[0007] A horizontal powder press 26 is illustrated in Figures 1, 2 and 3. An elongated compression chamber 27 of uniform quadrilateral cross section is formed by a bottom wall in the form of flat support 28, a pair of parallel side walls 31, 32 having confronting parallel vertical surfaces of equal height extending upwardly from the upwardly facing surface of the support 28 and a top wall 33 having a flat bottom surface in engagement with the coplanar top surfaces of the side walls 31, 32. A set of six opposed rib punches 36, 36' and a set of four opposed channel punches 37, 37' extend into opposite open ends of the compression chamber 27. The linearly reciprocable rib punches 36 and channel punches 37 are interleaved flat plates. The top wall 33 is held in place on the top surface of the side walls 31, 32 by a press foot 39 which has a vertically extending opening 41 for accommodating a wire 42 inserted through an opening 43 in the top wall 33 and into the powder compression chamber 27.

[0008] Four powered drive mechanisms 51, 52, 53, 54 are mounted on the support 28. The drive mechanism 51 includes an electric motor 56 secured to the support 28 and driving a horizontally disposed screw 57 which extends through a threaded opening 58 in a thrust block 59. The thrust block 59 has a T-bar tongue and groove connection 60 with the support 28 permitting the thrust block 59 to move in the axial direction of the screw 57 when the screw is rotated by the motor 56. The thrust block 59 includes a pair of cantilever arms 61 which are connected to the rib punches 36 by thrust bars 62. The drive mechanism 52 includes a powered driver in the form of an electric motor 66 having an output screw 67 in threaded engagement with an internally threaded opening 68 through a thrust block 69. The thrust block 69 has a T-

bar tongue and groove connection with the support 28. The thrust block 69 includes a cantilever arm 71 which is connected to the channel punches 37 by thrust bars 72.

[0009] The drive mechanisms 53, 54 in a similar manner include electric drive motors 76, 77, screws 78, 79 and screw blocks 81, 82 connected to the rib and channel punches 36', 37' by thrust arms 83, 84 and thrust bars 86, 87.

[0010] Figure 4 is a top view of an empty compression chamber 27 of the press 26 with the top wall 33 and the press foot 39 removed. The compression chamber 27 is ready to be filled with valve powder. The rib and channel punches 36, 36', 37, 37' have been adjusted to appropriate non-compacting or powder loading positions to achieve the desired degree of compaction during the compaction phase of operation. In the example illustrated in Figures 4 - 9 there is a 3 to 1 compaction ratio. Figure 5 shows the compaction chamber filled with valve powder 88. The top wall, not shown, is placed on top of the side walls 31, 32 and the press foot 39, not shown, is brought to bear against the top wall 33, not shown. The wire 42 is then extended an appropriate depth into the powder 88. The powder 88 is now ready to be compacted into a capacitor element. During, compression, in the illustrated example, there is a 3 to 1 reduction in the distance between the opposed ends of the rib punches 36, 36' and there is a 3 to 1 reduction in the distance between the ends of the channel punches 37, 37' during compression. Thus both the rib areas and the web areas between the opposed channels will be equally compressed, that is, compressed to the same degree or extent. Figure 6 shows the completion of the compaction step in the manufacturing process in which the rib and channel punches 36, 36', 37, 37' have been moved to their compacting position. The punches are moved from their non-compacting or chamber loading position shown in Figures 4 and 5 to their compacting position shown in Figure 6 at speeds proportional to the distances they move from their non-compressing

positions to their compressing positions. The rib punches 36, 36' move faster than the channel punches 37, 37' and both sets of punches arrive simultaneously at their compression or compaction positions shown in Figure 6. Thus the rate of compaction of the powder in the rib areas of the element 89 is the same as the rate of compaction in the web between the oppositely disposed channels in the element 89. By starting compaction with the punches spaced at distances proportional to the finished width of the rib and web areas of the capacitor element 89 and by moving the punches during compression at speeds proportional to the distances traveled during compression, an element 89 of uniform density is produced.

[0011] In the next manufacturing step, shown in Figure 7, the channel punches 37, 37' are withdrawn from the channels formed in the element 89 and for operational purposes may be withdrawn to their powder loading positions shown in Figures 4 and 5. By keeping the rib punches 36, 36' in their compacting position while the channel punches 37, 37' are withdrawn, breakdown of the edges of the formed element 89 are avoided.

[0012] As shown in Figure 8, the rib punches 36, 36' have been withdrawn and may be positioned in their chamber loading position shown in Figures 4 and 5. In the next step of manufacture, shown in Figure 9, the press foot 39 and the top wall 33 are raised and the side walls 31, 32 are moved laterally away from one another to completely release the element 89, which may now be removed without burnishing of the sides of the element 89.

[0013] Figures 10, 11 and 12 show a prior art press manufacturing a capacitor element. After the compaction chamber, formed by side walls 91, 92, a bottom wall, not shown, and opposed punches 93, 94, is filled with powder, as shown in Figure 10, and the top wall is closed, the opposed punches 93, 94 are moved to their compaction positions shown in Figure 11. Since the channel forming parts of the punches 93, 94 move the same distance as the rib forming parts,

the web areas between the channels are compressed to a greater extent than the ribs. The non-uniform compaction of the element is highly undesirable from a capacitor quality standpoint. When the punches 93, 94 are released or withdrawn, as shown in Figure 12, portions of the element tend to break away because the pressure of the compacted powder within the confines of the punches is greater than the tensile strength of the compacted element. The foregoing deficiencies in the illustrated prior art powder compaction press are remedied by the herein disclosed invention.

[0014] Figure 13 is a perspective view of the capacitor element 89 formed by the press 26. Figures 14 shows a capacitor element 96 with three wires and Figures 15 and 16 show a capacitor element 97 which has been formed, according to this invention, using a single pair of opposed rib punches and two pair of opposed channel punches.

[0015] Figures 17 and 18 schematically illustrate a vertical press 101 embodiment of the invention. Four powered drive mechanisms 102, 103, 104, 106 are secured to a vertical support wall 107 and a valve powder compaction chamber 108 is formed by the vertical wall 107, side walls 111, 112, 113 and sets of opposed rib punches 116, 116' and sets of opposed channel punches 117, 117' which are supported in guide blocks 121, 122 mounted on the vertical wall 107. The side walls 111, 112, 113 are releasably held in place by press feet 131, 132, 133. Drive screws 136, 137, 138, 139 driven by electric motors 141, 142, 143, 144, threadingly engage threaded openings in thrust blocks 146, 147, 148, 149 which have siding tongue and groove connections with the wall 107 similar to that provided for the embodiment of the invention shown in Figures 1 – 3. The support wall 107 has an opening 161 through which a capacitor wire 162 can be inserted into the compaction chamber 108.

[0016] Figure 19 shows the upper rib punches 116 and the upper channel punches 117 withdrawn from the compression chamber 108 sufficiently to permit valve powder to be placed in the compression chamber 108. The upper ends of the lower rib and lower channel punches 116', 117' are positioned to provide the desired amount of powder 151 for the element to be formed when the chamber 108 is filled to the top. The upper rib and channel punches 116, 117 are then lowered to close the top opening of the compression chamber 108 as shown in Figure 20.

[0017] As shown in Figure 21 the upper and lower channel punches 117, 117' are next adjusted to extend an equal distance into the compression chamber 108. This is accomplished by simultaneously lowering the upper and lower channel punches 117, 117' the same distance. The press is now ready for the compaction step. It will be noted that the wire 162 is centrally located in relation to the powder 151 to be compressed, the punches 116 and 116' are spaced equal distances from a horizontal plane 152 through the center of the wire 162 and the punches 117, 117' are also spaced equal distances from the horizontal plane 152. The element 153 shown in Figure 22 is formed by a three to one compression of the powder 151. In other words the distance between the opposed rib punches 116 and 116', shown in Figure 21, is reduced to one third in the compression step. Likewise the distance between the opposed channel punches 117, 117" shown in Figure 21, is also reduced to one third in the compression step. In order to effect an equal rate of compression in the rib and web areas of the element, the opposed rib punches 116, 116' are moved toward one another faster than the channel punches 117, 117' are moved toward one another. The ratio of the speeds at which the rib and channel punches move in the compaction step is equal to the ratio of the distances said rib and channel punches move during the compaction step. An equal rate of compaction of the powder in the rib areas and the web

areas between the channels is effected, thus avoiding lateral shifting of the powder during compaction. A uniform compaction density of the element 153 is achieved.

[0018] Following the compaction step illustrated by Figure 22 the channel punches 117, 117' are retracted by the drive mechanisms 102, 103, 104, 106 from the element 153 and next the rib punches 116, 116' are retracted to a non-compacting position. Then the side walls 111, 112 and 113 are moved away from the element 153 to permit the element 153 to be removed without burnishing its surfaces. This retraction of the punches 116, 116', 117, 117' and shifting of the side walls is similar to the procedure employed in fabricating the element 92 by the horizontal press shown in Figures 1 – 9.

[0019] The herein disclosed horizontal press 26 and the vertical press 101 carry out a method of manufacturing a capacitor element which produces high quality capacitor elements having uniform compaction density and unburnished surfaces free of defects.